NAVSHIPS 91073(A) T. O. 33A1-12-15-21

INSTRUCTION BOOK

for

RESISTANCE BRIDGE

ZM-4/U

LEEDS & NORTHRUP COMPANY

PRINTED FOR USAF DISTRIBUTION 25 JUNE 1956. PRIOR PRINTING FOR NAVY ONLY.

Published by Direction of the Chief, Bureau of Ships, and Accepted by the Secretary of the Air Force

AF Olmsted May 63, 800

8 Dec 1950

LIST OF REVISED PAGES ISSUED

INSERT LATEST REVISED PAGES. DESTROY SUPERSEDED PAGES.

NOTE: The portion of the text affected by the current revision is indicated by a vertical line in the outer margins of the page.

* The asterisk indicates pages revised, added or deleted by the current revision.

ADDITIONAL COPIES OF THIS PUBLICATION MAY BE OBTAINED AS FOLLOWS:

USAF ACTIVITIES.—In accordance with Technical Order No. 00-5-2.
NAVAL ACTIVITIES.—Use Publications and Forms Order Blank (NavAer 2126) and submit to the nearest publications supply point listed below: NAS, Alameda, Calif.; NAS, Jacksonville, Fla.; NAS, Norfolk, Va.; NAS, San Diego, Calif.; NAS, Seattle, Wash.; NASD, ASO, Guam; NASD, Philadelphia, Pa.
For listing of available publications see Naval Aeronautic Publications Index (NavAer 00-500).

USAF

TABLE OF CONTENTS

SECTION 1—GENERAL DESCRIPTION

Paragraph *Page*

1. Purpose and Basic Principal 1-1
2. Description of Instrument 1-1
3. Reference Data 1-1

SECTION 2—THEORY OF OPERATION

1. General Description of Circuit 2-1

SECTION 3—INSTALLATION

1. Unpacking 3-1
2. Assembling 3-1

SECTION 4—OPERATION

1. Introduction 4-0
2. Determine D-C Supply to be Used 4-0
3. Determine Galvanometer to be Used 4-1
4. Adjust Galvanometer Zero 4-1
5. To Make Measurements 4-1
   a. Resistance Measurements 4-1
   b. To Pick Out a Grounded Wire 4-1
   c. Murray Loop Test 4-1
      (1) Ground on a Wire of a Cable 4-1
      (2) A Cross in a Cable 4-2
   d. Varley Loop Test 4-2
      (1) Ground on a Wire of a Cable 4-2
      (2) A Cross in a Cable 4-4
   e. Simple Varley Test 4-4
   f. Three Varley Method 4-4
   g. Open Location—Quadded Cable 4-4
   h. Open Location—Pairs 4-5
6. To Use Instrument Rheostat as a Resistance Box 4-5

SECTION 5—OPERATOR'S MAINTENANCE

1. Battery 5-0
2. Galvanometer 5-0

SECTION 6—PREVENTIVE MAINTENANCE

1. General 6-1

SECTION 7—CORRECTIVE MAINTENANCE

1. Theory of Localization 7-1

SECTION 8—PARTS LISTS

LIST OF ILLUSTRATIONS

SECTION 1—GENERAL DESCRIPTION

Figure	Title	Page
1-1	Resistance Bridge ZM-4/U	1-0

SECTION 2—THEORY OF OPERATION

Figure	Title	Page
2-1	Simplified Diagram of Resistance Bridge ZM-4/U	2-0
2-2	Theoretical Diagram of a Conventional Bridge	2-0
2-3	Theoretical Diagram for Comparison of Capacitances to Locate an Open in a Cable	2-0

SECTION 3—INSTALLATION

Figure	Title	Page
3-1	Resistance Bridge ZM-/U, Left hand end	3-1

SECTION 4—OPERATION

Figure	Title	Page
4-1	Resistance Bridge ZM-4/U Operating Panel	4-0
4-2	Resistance Bridge ZM-4/U Internal Wiring	4-2
4-3	Standard Resistance Measurements	4-3
4-4	To Pick Out a Grounded Wire in a Cable	4-3
4-5	Murray Loop Tests	4-3
4-6	Regular Varley Loop Tests	4-3
4-7	Three Varley Method	4-3
4-8	Open Location—Quadded Cable	4-3
4-9	Open Location—Pairs	4-3

SECTION 6—PREVENTIVE MAINTENANCE

Figure	Title	Page
6-1	Resistance Bridge ZM-4/U, Under Side of Operating Panel from Rear Edge	5-0

SECTION 7—CORRECTIVE MAINTENANCE

Figure	Title	Page
7-1	Resistance Bridge ZM-4/U, Operating Panel	7-1
7-2	Resistance Bridge ZM-4/U, Showing Dry Cell Compartment	7-2
7-3	Resistance Bridge ZM-4/U, Under Side of Operating Panel from Front Edge	7-3
7-4	Resistance Bridge ZM-4/U, Detail of Click Ball and Spring	7-3
7-5	Resistance Bridge ZM-4/U, Under Side of Operating Panel from Rear Edge	7-4
7-6	Resistance Bridge ZM-4/U, Actual Wiring and Wire Sizes	7-4
7-7	Resistance Bridge ZM-4/U, Elementary Wiring	7-5

LIST OF TABLES

SECTION 1—GENERAL DESCRIPTION

Table	Title	Page
1-1	Equipment Supplied	1-1
1-2	Shipping Data	1-1

SECTION 8—PARTS LISTS

Table	Title	Page
8-1	Replaceable Parts	8-0
8-2	Cross Reference Parts List	8-8

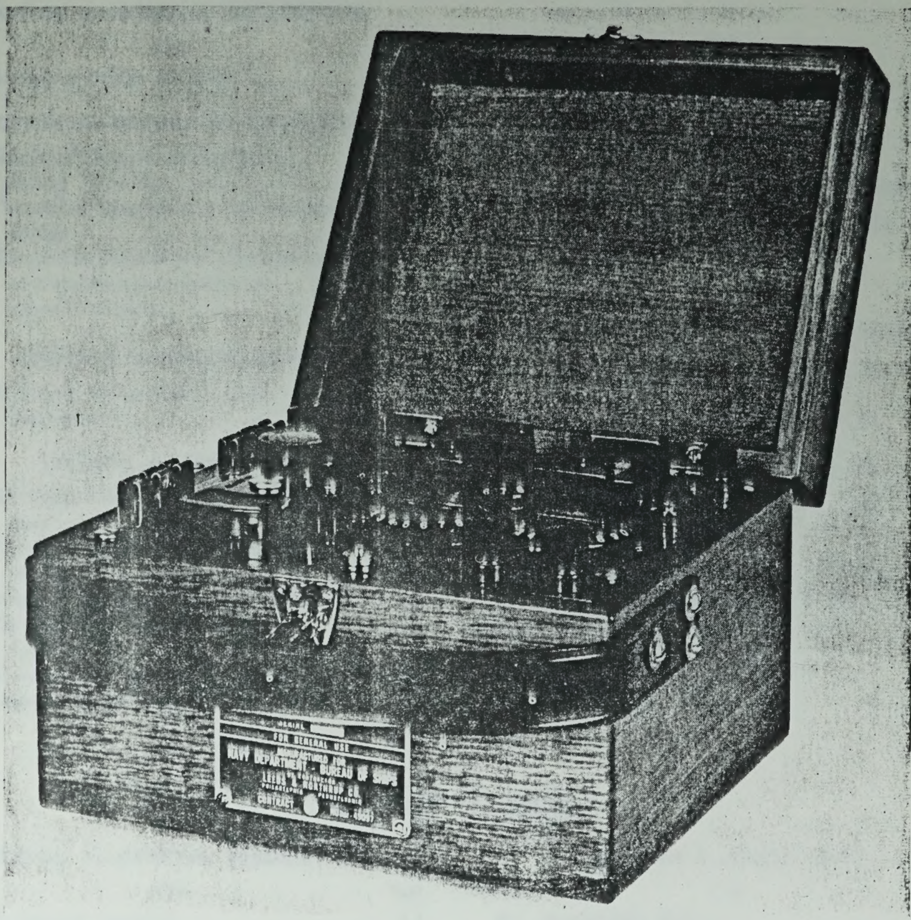

Figure 1-1. Resistance Bridge ZM-4/U

SECTION 1
GENERAL DESCRIPTION

1. PURPOSE AND BASIC PRINCIPLE.

Resistance Bridge ZM-4/U is a readily portable instrument, weighing approximately 8 pounds, arranged primarily to measure resistances in locating faults which occur on conductors used for communication systems and on those used for power transmission. It can also be used to measure other fixed resistances.

2. DESCRIPTION OF INSTRUMENT.

A general view of the instrument, with the lid open, is shown in figure 1-1. It is contained in an oak case with a hinged lid which is equipped with a snap latch. The carrying strap is long enough to permit carrying by hand but it is not long enough to permit slinging the instrument from the shoulder.

The instrument is self-contained, in that it has a galvanometer mounted in the top plate and three dry cells (flash light type) mounted in a compartment in the case. The dry cells supply the current for the measuring circuit.

On the other hand, readily accessible terminals are provided so that a separately mounted galvanometer can be used and so that external dry cells can be used, if desired. When either the external dry cells or galvanometer is used, the corresponding internal item must be disconnected. This feature is covered in detail in Section 3, Installation.

3. REFERENCE DATA.

a. Resistance Bridge ZM-4/U.
b. Contract NObsr-49097: 31 May 1950.
c. Leeds & Northrup Company.
d. Inspector of Naval Material, Washington, D. C.
e. One package per instrument and only one instrument involved.
f. Cubical contents: crated 1.7 cu. ft.; uncrated 0.22 cu. ft.
g. Weight: crated 45 lb.; uncrated 9 lb.
h. Accuracy of instrument: 0.15% from 1 ohm up to the limit of the use of the instrument.

TABLE 1-1. EQUIPMENT SUPPLIED

QUANTITY PER EQUIPMENT	NAME OF UNIT	NAVY TYPE DESIGNATION	OVER-ALL DIMENSIONS			VOLUME	WEIGHT
			HEIGHT	WIDTH	DEPTH		
1	Resistance Bridge	ZM-4/U	5⅝	9	7½	0.22	8
2	Instruction Books	NAVSHIPS 91073(A)	11	8½	......	......	......
3	Flashlight Cells	....	2 5/16	1 5/16 diam.	......	0.09	1

Unless otherwise stated, dimensions are inches, volume cubic feet, weight pounds.

TABLE 1-2. SHIPPING DATA

SHIPPING BOX NO.	CONTENTS		OVER-ALL DIMENSIONS			VOLUME	WEIGHT
	NAME	DESIGNATION	HEIGHT	WIDTH	DEPTH		
1	Resistance Bridge	ZM-4/U	10	18	16	1.7	45

Unless otherwise stated, dimensions are inches, volume cubic feet, weight pounds.

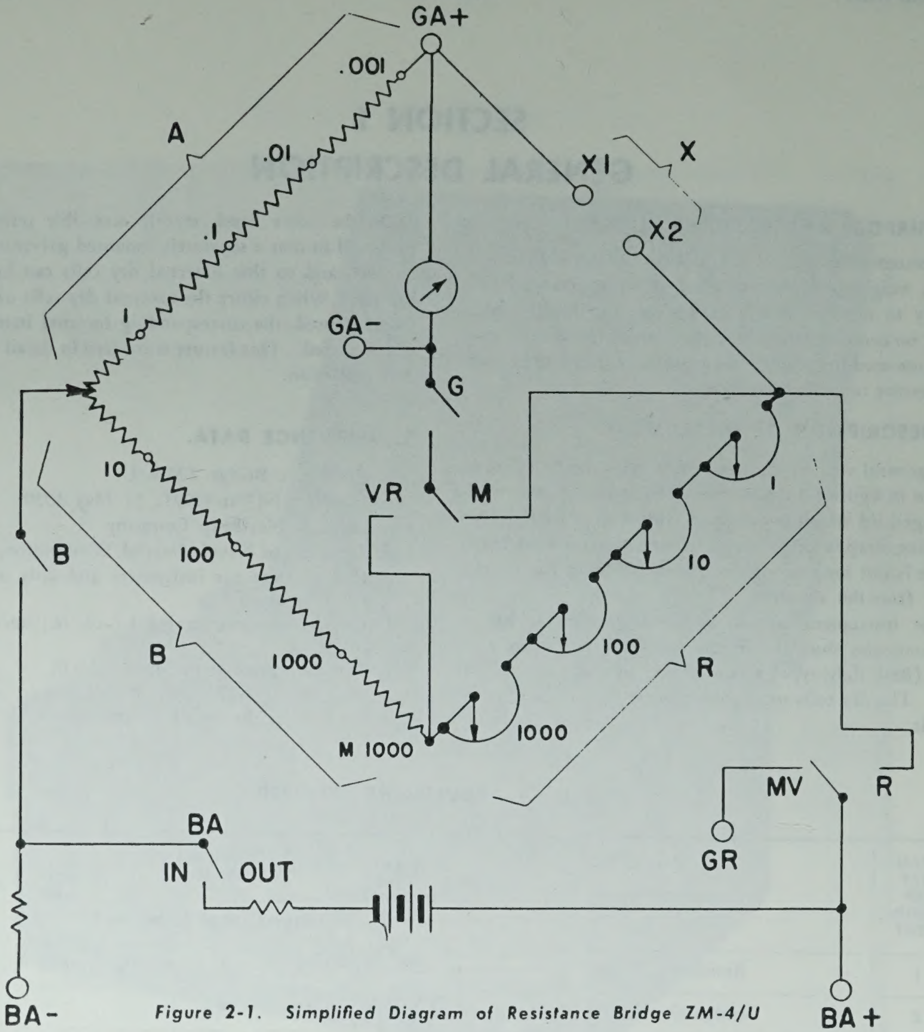

Figure 2-1. Simplified Diagram of Resistance Bridge ZM-4/U

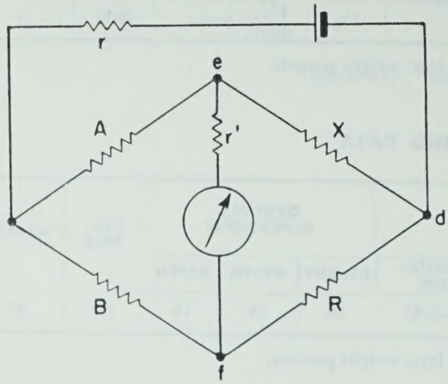

Figure 2-2. Theoretical Diagram of a Conventional Bridge

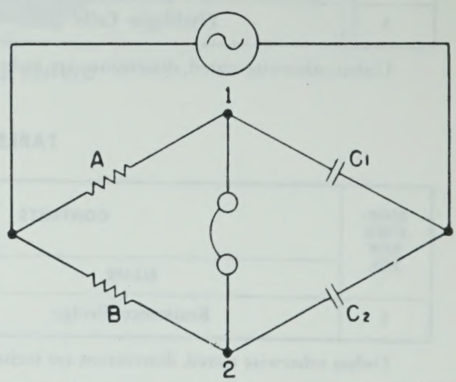

Figure 2-3. Theoretical Diagram for Comparison of Capacitances to Locate an Open in a Cable

SECTION 2
THEORY OF OPERATION

1. GENERAL DESCRIPTION OF CIRCUIT.

The internal wiring connections, of Resistance Bridge ZM-4/U, are shown in the conventional form in figure 2-1. It is to be noted, however, that the taps for positions M10 and M100 on the MULTIPLY BY (ratio) dial have been omitted from figure 2-1 for simplicity. This does not change the connections which are shown and does not affect the general operation and functioning of the circuit. The connections for positions M10 and M100 are shown in figure 4-2.

To further simplify the explanation of the circuit, the connections are shown in figure 2-2 as a conventional bridge. In figure 2-2, R represents the four resistance dials 1, 10, 100 and 1000 in figure 2-1 while A and B in figure 2-2 represents the two ratio arms shown by the series of resistors in figure 2-1.

The references used in the following description are to figure 2-2, unless otherwise stated.

Grounds and crosses on land lines, and on short submarine cables, are generally located by what are commonly called loop methods. Each of these methods utilizes a special arrangement of the bridge circuit and must satisfy bridge balanced conditions to obtain a correct reading. The conventional bridge circuit is shown in figure 2-2 with resistors A, B, R and X forming the four arms of the bridge; the galvanometer connected between points e and f; and the battery (for current supply) connected between points c and d.

The bridge is balanced, with no current flowing through the galvanometer, when resistances have the relation,

$$\frac{A}{B}=\frac{X}{R} \qquad (2)$$

If the values of resistances A, B and R are known, the value of X may be calculated from the relation,

$$X=\frac{A}{B}R \qquad (2a)$$

Resistances A and B are called the ratio arms. Their ratio only, not their individual values, need be known. In the case of the ZM-4/U, these ratios are covered by the MULTIPLY BY dial, figure 4-1. Resistance R is called the rheostat arm. It should be adjustable in small steps of resistance over a wide range of values. In the case of the ZM-4/U, this arm is covered by the four dials 1, 10 100 and 1000, figure 4-1.

The resistance to be measured (X in figure 2-2) is connected to terminals X1 and X2 (see figure 4-1) on the instrument.

Each of the resistances A, B, R and X, respectively, represents the total resistance, including lead and contact resistance, from a battery connection to the next galvanometer connection. Therefore, the resistance of the leads from the terminals on the instrument to the resistance being measured, must be considered in subsequent calculations.

The introduction or variation of resistances (as represented by r and r′ in figure 2-2) in the battery or galvanometer circuit does not affect the conditions of balance. The effect of such resistances is to change the sensitivity and to vary the damping of the galvanometer.

Thus, this Resistance Bridge ZM-4/U is arranged to measure an unknown resistance in a very simple and quick manner. However, certain types of faults on wires and cables can be located by measuring resistance of the wires with specific special connections of the bridge circuit. For these details, refer to Section 4, Operation.

In addition, this Resistance Bridge ZM-4/U can be used (with modified circuit connections) to locate an open in a wire. For these details, refer to Section 4, Operation. However, a theoretical discussion of this type of measurement is given below.

Figure 2-3 shows the theoretical connections for making a measurement to locate an open in a wire by using the comparison of capacitances method.

When a conductor is actually broken and there is no return circuit from the break, a new set of conditions must be considered. In locating the break, use is made of the fact that every conductor possesses capacitance with reference to any neighboring conductors and forms with them a capacitor. The conductor itself forms one plate; the neighboring conductors, cable sheath or earth, the other plate; the cable insulation, air or other insulating material, the dielectric of the capacitor.

When the conductor is uniformly spaced from its surroundings as, for example, a conductor in a cable, the capacitance is proportional to the length. Therefore, by measuring the capacitance of the conductor from one end to the break, the distance to the break may be determined, if the capacitance per unit length is known. This may be done by charging the capacitor (by applying a voltage) and then discharging it through a galvano-

meter. The resulting ballistic deflection or "kick," if calibrated by applying the same voltage to a standard capacitor, is a measure of the capacitance of the conductor to its surroundings and, hence, of the distance to the break. This method is, however, subject to objections: the capacitance may not be uniform throughout the length of the cable; and "dielectric absorption" (retention of a part of the charge by the dielectric) may introduce errors.

By balancing the capacitance of the faulty conductor up to the point of the break against that of a good conductor in the same cable, these sources of error may be largely eliminated, as they affect both the faulty and good conductors in substantially the same way. This is accomplished by using the same apparatus which is used for locating grounds and shorts, except that direct current from a battery is replaced by pulsating or alernating current from a buzzer or "tone test" set, and the galvanometer is replaced by phones. A buzzer may be used for distances up to ½ mile, with lower frequencies or slowly-reversed, direct current from longer lines.

The connections used are essentially those of a bridge (compare figure 2-3 with figure 2-2) with resistances X and R, in figure 2-2, replaced by the two capacitors C1 and C2, in figure 2-3, formed by the faulty conductor and the good conductor. When resistances A and B, figure 2-3, are so adjusted that no sound is heard in the phones, points 1 and 2 are at equal potentials. If the phones cannot be adjusted to silence, the point of minimum sound is determined.

The cable capacitances represented by C1 and C2 are charged to the same difference of potential, as indicated by no sound in the phones, and contain quantities of electricity proportional to their respective capacitances. The quantity flowing into each capacitor in any unit of time is limited, however, by the resistance in series with it and, hence, is inversely proportional to the resistance limiting the flow.

Therefore

$$\frac{A}{B} = \frac{C2}{C1} \qquad (2b)$$

Since the good and faulty conductors are subjected to the same conditions, their lengths may be taken as proportional to their capacitances, from which

$$\frac{A}{B} = \frac{L2}{L1} \qquad (2c)$$

The question of allowance for leadwires does not arise unless the leads are very long or unless wire in a cable is used for leads to the faulty cable.

SECTION 3

INSTALLATION

1. UNPACKING.

No special precautions need be used in unpacking this instrument. Simply use the care which should be used in unpacking any portable electrical instrument.

Just inside the wooden shipping box there is one thickness of waterproof paper; under this there is a waxed cloth which covers the cardboard carton containing the instrument. Use normal care in opening the carton so as not to damage the wood case of the instrument. One or more small bags of a desiccant (dryer) will be found inside the carton. These are for shipping purposes only.

Three, size D, flashlight, dry cells are also packed in the carton with the instrument. Be sure they are not discarded with the packing material.

2. ASSEMBLING.

The only assembling necessary is to mount the three dry cells in the instrument case. To do this, remove the two screws 1, figure 3-1, and remove metal plate 2, figure 3-1, to uncover the dry cell compartment. Insert the three, size D, flashlight dry cells in series in this compartment, inserting the bottom of the cells first, so that the center terminal on the last cell will make contact with the metal cover plate when it is replaced. Then replace plate 2, figure 3-1, and fasten it in place with the two screws.

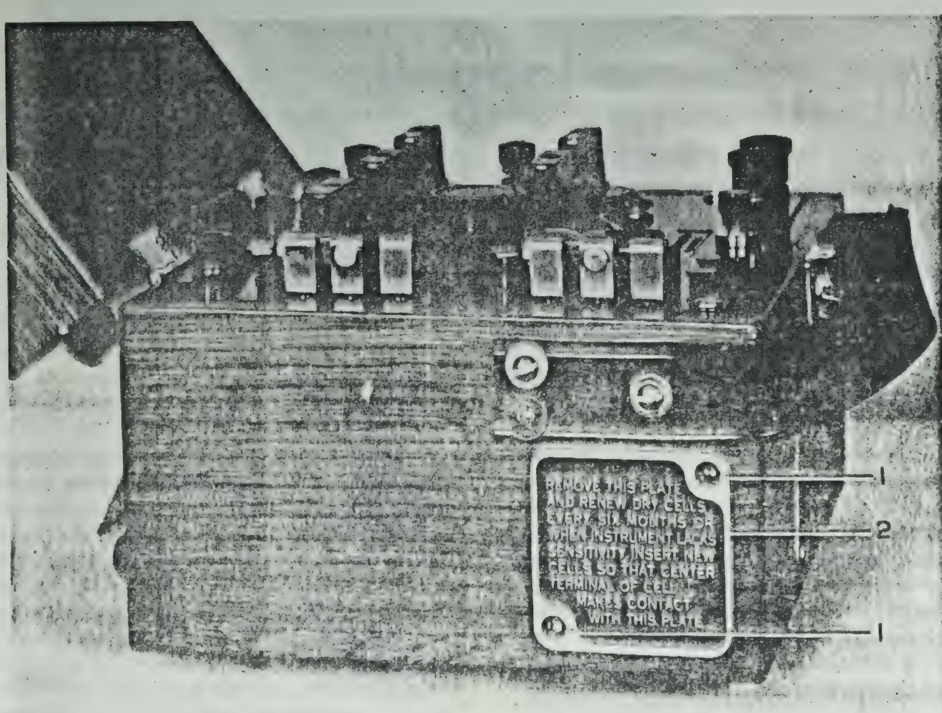

Figure 3-1. Resistance Bridge ZM-4/U, Left Hand End

SECTION 4
OPERATION

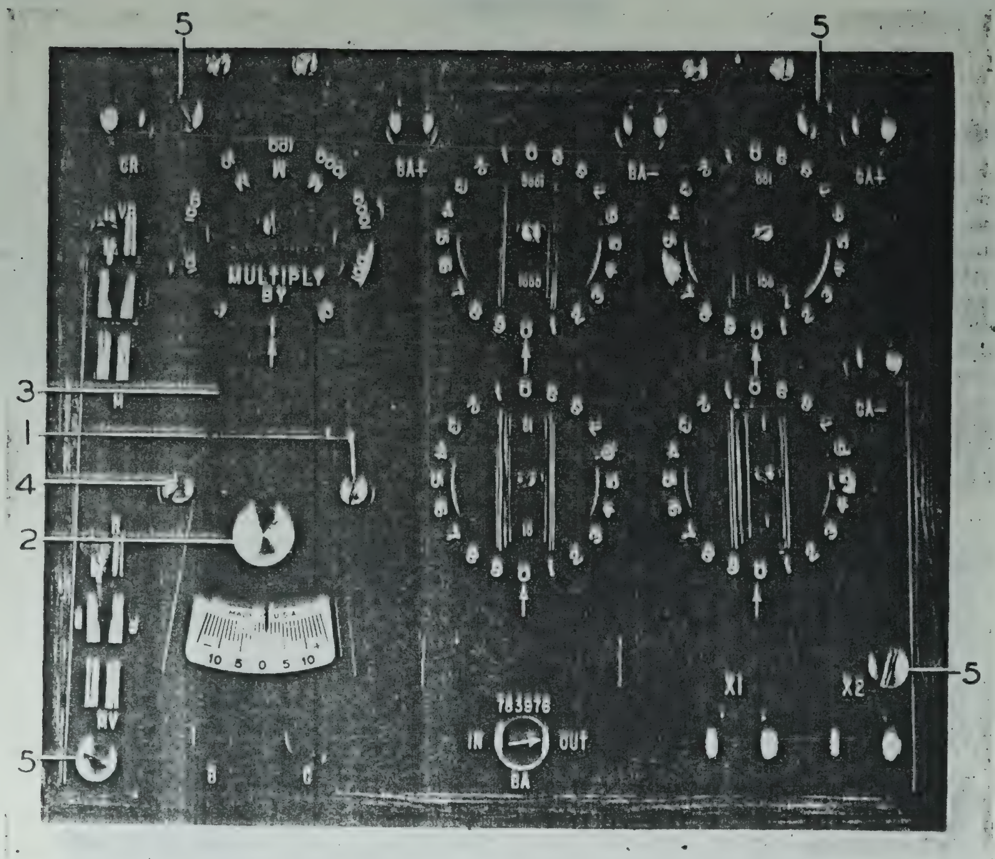

Figure 4-1. Resistance Bridge ZM-4/U, Operating Panel

1. INTRODUCTION.

Before using this instrument for a measurement, certain operating adjustments must be made and the decision made as to whether to use the dry cells and galvanometer mounted in the instrument case or to use external dry cells (or battery) and an external galvanometer. The external battery or galvanometer is used only when it is necessary to increase the sensitivity of measurement. This is determined primarily from experience.

When key G is depressed it closes and completes the circuit to the galvanometer and when key B is depressed it closes and completes the circuit to the battery (or other d-c supply). Both of these keys must be closed (depressed) at the same time in order to make a measurement.

2. DETERMINE D-C SUPPLY TO BE USED.

If the battery (three dry cells) mounted in the instrument case is to be used (sensitivity of the instrument sufficient on approximately 4.5 volts), turn the BA key, figure 4-1, with the arrow toward IN.

If the battery mounted in the instrument case is not sufficient for the desired sensitivity, turn key BA with the arrow toward OUT. Then connect the required battery, or higher voltage d-c source, to terminals BA+ and BA— with polarities as indicated. The maximum d-c voltage permissible for this purpose is 200 volts. For potentials over 45 volts, use an external resistance in series with it. This resistance should equal 40 ohms for each volt over 45, up to 200.

3. DETERMINE GALVANOMETER TO BE USED.

If the galvanometer which is mounted in the instrument is usable and has sufficient sensitivity for the measurement to be made, do not make any connections to terminals GA+ and GA—.

If the galvanometer which is mounted in the instrument is damaged or does not have sufficient sensitivity for the measurement to be made, remove screw 1, figure 4-1, to disconnect this galvanometer. Then connect the external galvanometer to terminals GA+ and GA—. The polarity markings can be ignored unless it is desired to have the galvanometer deflect in a given direction for a given unbalance of the measuring circuit.

4. ADJUST GALVANOMETER ZERO.

Before making a measurement, check and, if necessary, adjust the galvanometer zero.

If the galvanometer in the instrument is used, adjust the zero as follows: See that key G, figure 4-1, is open (in the up position). Push CLAMP button 2, figure 4-1, toward the galvanometer scale as for as it will go to release the coil. If the galvanometer pointer balances at zero on the scale, it needs no adjusting. On the other hand, if it does not balance at zero, loosen the small screw in the side of cap 3, figure 4-1, and turn cap 3 until this condition is obtained. To clamp the galvanometer coil, when finished using the instrument, push CLAMP button 2, figure 4-1, in the direction of the arrow at CLAMP as far as it will go. This prevents the coil from swinging while transporting the instrument.

If an external galvanometer is used (connected to terminals GA+ and GA—), adjust its zero as indicated in the separate instructions for this galvanometer.

5. TO MAKE MEASUREMENTS.

a. RESISTANCE MEASUREMENTS

This type measurement may be a long length of wire, two long lengths of wire joined at the distant ends, a wound resistor, etc. The connections for this type measurement are shown, in schematic form, in figure 4-3.

Connect the unknown resistance to terminals X1 and X2. Close one knife switch in the R position and the other in the VR position. Set the MULTIPLY BY (ratio) dial to the proper value as indicated in the following table.

Unknown Resistance	MULTIPLY BY Dial Setting
Below 10 ohms	1/1000
10 ohms to 100 "	1/100
100 " " 1000 "	1/10
1000 " " 10000 "	1/1
10000 " " 100000 "	10/1
100000 " " 1000000 "	100/1
1000000 " " 10000000 "	1000/1

Balance the bridge by adjusting the four rheostat dials (1, 10, 100 and 1000) until the galvanometer does not deflect when keys G and B are depressed (closed) at the same time. Then the unknown resistance (in ohms) is equal to the sum of the rheostat dial setting multiplied by the setting of the MULTIPLY BY dial. In other words, from figure 4-3,

$$X = \frac{A}{B}R \qquad \text{where}$$

$\frac{A}{B}$ = setting of MULTIPLY BY dial

R = sum of settings of rheostat dials

b. TO PICK OUT A GROUNDED WIRE

The connections for this type measurement are shown, in schematic form, in figure 4-4.

Set the MULTIPLY BY dial at M1000. Close one knife switch in the VR position and the other knife switch in the MV position. Connect terminal GR to a good ground. Then connect the wires in the cable, one after the other to terminal X1. The faulty wire will be detected by a strong galvanometer deflection when keys B and G are depressed at the same time.

The pointer will deflect a scale division for 1 volt through 1 megohm, hence a very high resistance ground or fault can be detected.

c. MURRAY LOOP TEST

(1) GROUND ON A WIRE OF A CABLE

The connections for this type measurement are shown in figure 4-5.

Where there is a ground on a wire, join the faulty wire to a good one at the distant end. Then connect the near end of the faulty wire to terminal X2 and the good one to terminal X1. Connect terminal GR to a good ground. Set the MULTIPLY BY dial at M1000, which places 1000 ohms in the A ratio arm (see figure 4-5) and leaves zero ohms in the B ratio arm. Place one knife switch in the M position and the other in the MV position. Adjust the four rheostat dials (1, 10, 100 and 1000) to obtain a bridge balance. If a satisfactory bridge balance cannot be obtained with the MULTIPLY BY dial set at M1000, set it at M100 or M10 as required. Read the setting of the MULTIPLY BY dial and the sum of the settings of the four rheostat dials.

To obtain the resistance Xa (see figure 4-5) to the ground on the faulty wire, use the formula below.

To obtain the value of r to be used in this formula, proceed as follows: Allow the connections to remain as above, except for the two knife switches. Place one

switch on the R position and the other in the VR position. Then balance the bridge, to measure the total resistance of the loop, as indicated in Section 4 a.

$$Xa = \frac{Rr}{A+R} \qquad \text{where}$$

Xa = resistance of faulty wire, from instrument to fault

A = M setting of MULTIPLY BY dial

R = sum of settings of four rheostat dials

r = resistance of loop

To convert resistance Xa into distance to the fault, multiply the value of Xa by the feet per ohm for the proper wire size.

(2) A CROSS IN A CABLE

Where there is a cross in a cable, connect one crossed wire to terminal X2 and a good wire to terminal X1. Join the distant ends of these wires. Connect the other crossed wire to terminal GR. Set the MULTIPLY BY dial at M1000, which places 1000 ohms in the A ratio arm (see figure 4-5) and leaves zero ohms in the B ratio arm. Place one knife switch in the M position and the other in the MV position. Adjust the four rheostat dials (1, 10, 100 and 1000) to obtain a bridge balance. If a satisfactory bridge balance cannot be obtained with the MULTIPLY BY dial set at M1000, set it at M100 or M10 as required. Read the setting of the MULTIPLY BY dial and the sum of the settings of the four rheostat dials for use in the formula just preceding this paragraph.

To obtain the value of r to be used in this formlua, proceed as follows: Allow the connections to remain as above, except for the two knife switches. Place one switch in the R position and the other in the VR position. Then balance the bridge, to obtain the total resistance of the loop, as indicated in Section 4 a.

To convert resistance Xa into distance to the fault, multiply the value of Xa by the feet per ohm for the proper wire size.

d. VARLEY LOOP TEST

(1) GROUND ON A WIRE OF A CABLE

The connections for this type measurement are shown in figure 4-6.

Where there is a good ground wire, join the faulty wire to a good one at the distant end. Connect the faulty wire to terminal X2 and the good one to terminal X1. Connect terminal GR to a good ground. Place one knife switch in the VR position and the other in the MV position. Set the MULTIPLY BY dial at .1 or .01. Adjust the four rheostat dials (1, 10, 100 and 1000) to obtain a bridge balance. The sum of the dial settings is the value of R in the formula below.

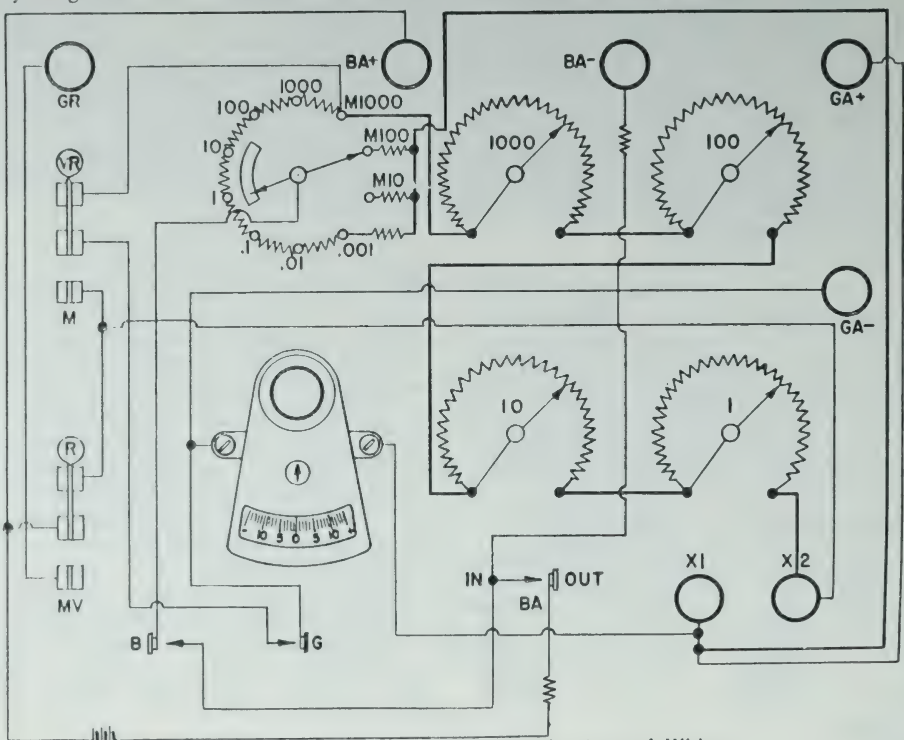

Figure 4-2. Resistance Bridge ZM-4/U, Internal Wiring

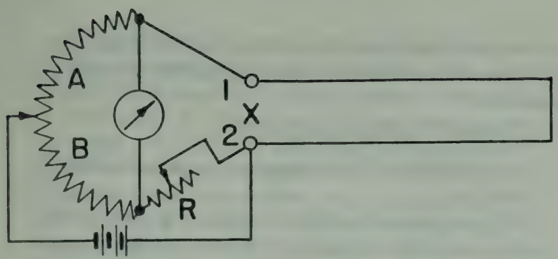

Figure 4-3. Standard Resistance Measurements

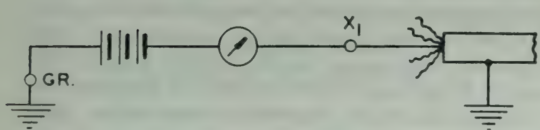

Figure 4-4. To Pick Out a Grounded Wire

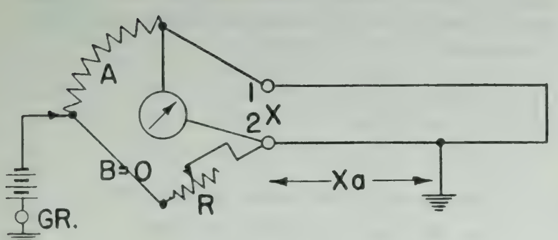

Figure 4-5. Murray Loop Tests

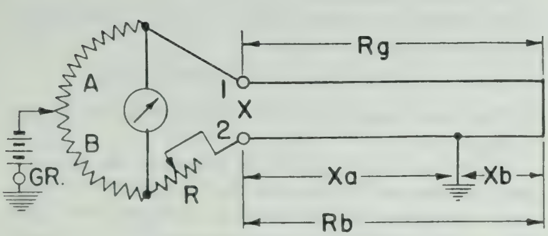

Figure 4-6. Regular Varley Loop Tests

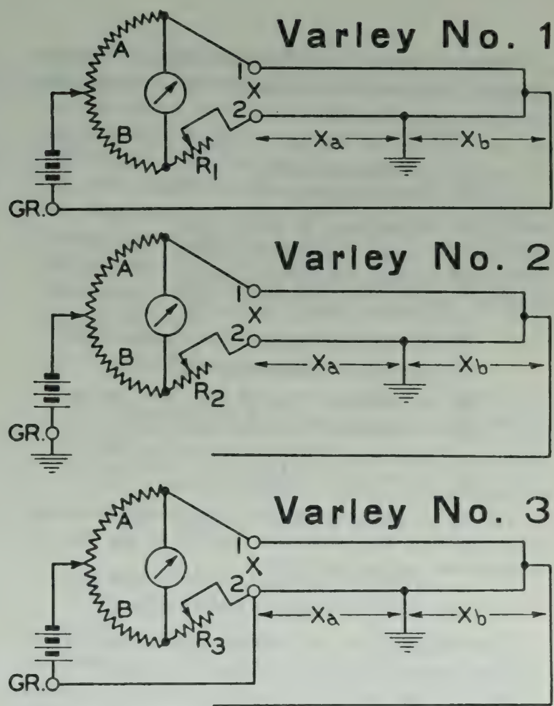

Figure 4-7. Three Varley Method

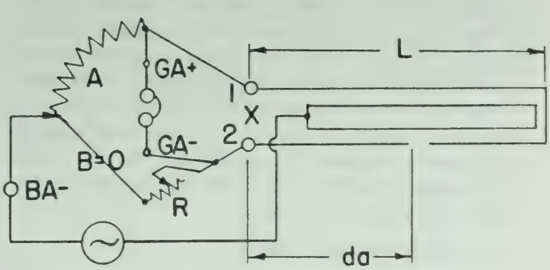

Figure 4-8. Open Location—Quadded Cable

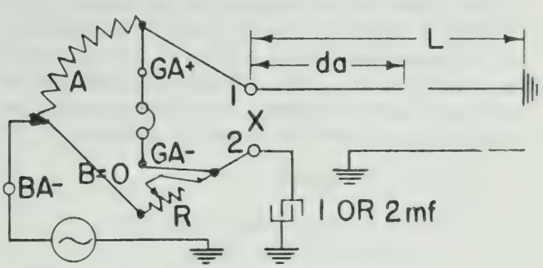

Figure 4-9. Open Location—Pairs

Measure the total resistance of the loop as indicated in Section 5 a and use this value for r in the formula below.

$$Xa = \frac{rB - AR}{A + B}$$

$$Xb = \frac{A(R+Rb)-BRg}{A + B} \quad \text{where}$$

Xa = resistance of faulty wire from instrument to fault

Xb = resistance of faulty wire from distant end to fault

R = sum of settings of four rheostat dials

r = total resistance of loop

Rg = resistance of good wire used in test

Rb = resistance of faulty wire used in test

$\frac{A}{B}$ = setting of MULTIPLY BY dial

To convert resistance Xa or Xb into distance to the fault, multiply the value of Xa or Xb by the feet per ohm for the proper wire size.

(2) A CROSS IN A CABLE

Where there is a cross in a cable, connect one crossed wire to terminal X2 and a good wire to terminal X1. Join the distant ends of these wires. Connect the other crossed wire to terminal GR. Place one knife switch in the VR position and the other in the MV position. Set the MULTIPLY BY dial at .1 or .01. Adjust the four rheostat dials (1, 10, 100 and 1000) to obtain a bridge balance. The sum of the dial settings is the value of R, to be used in the formula just preceding this paragraph.

Measure the total resistance of the loop as indicated in Section 5 a and use this value for r in the same formula.

To convert resistance Xa or Xb into distance to the fault, multiply the value of Xa or Xb by the feet per ohm for the proper wire size.

e. SIMPLE VARLEY TEST

For this test, the good and bad wires must be equal in resistances.

Make connections as indicated for the regular VARLEY LOOP TEST. Set the MULTIPLY BY dial at 1 and adjust the four rheostat dials (1, 10, 100 and 1000) for a bridge balance. The resistance from the fault to the jointed ends of the wires (at the distant end of the cable) is obtained from the formula given below.

$$Xb = \frac{R}{2} \quad \text{where}$$

Xb = resistance of faulty wire from distant end to fault

R = sum of settings of four rheostat dials

To convert resistance Xb in distance to the fault, multiply the value of Xb by the feet per ohm for the proper wire size.

f. THREE VARLEY METHOD

The connections for this type measurement are shown in figure 4-7.

This method requires three readings of R (sum of the four rheostat dials) with slightly different connections as shown in the three diagrams of figure 4-7. Place one knife switch in the VR position and the other in the MV position for all three readings of R. Place the MULTIPLY BY dial at position .1 for all three readings of R.

For test No. 1 (see figure 4-7), join the faulty wire to two good ones at the distant end of the cable. Connect the faulty wire to terminal X2, one good wire to terminal X1, and the other good wire to terminal GR. Then adjust the four rheostat dials for a bridge balance. The sum of the settings of these dials is R1 in formula below.

For test No. 2 (see figure 4-7), disconnect the good wire from terminal GR and connect this terminal to a good ground. Again adjust the four rheostat dials for a bridge balance and call the sum of their settings R2 in the formula below.

For test No. 3 (see figure 4-7), disconnect the ground from terminal GR and connect this terminal to terminal X2. Again adjust the four rheostat dials for a bridge balance and call the sum of their settings R3 in the formula below.

$$Xb = \frac{A}{A + B}(R2 - R1)$$

$$Xa = \frac{A}{A + B}(R3 - R2) \quad \text{where}$$

R1, R2 and R3 are the readings noted above

Xb = resistance of faulty wire from distant point to fault

$\frac{A}{B}$ = setting of MULTIPLY BY dial

Xa = resistance of faulty wire from instrument to fault

To convert resistance Xa or Xb into distance to the fault, multiply the value of Xa or Xb by the feet per ohm for the proper wire size.

g. OPEN LOCATION—QUADDED CABLE

The connections for this type measurement are shown in figure 4-8.

Remove screw 1, figure 4-1, to disconnect the galvanometer. Turn the BA switch to the OUT position. Connect a telephone receiver between terminals GA+ and GA—. Connect the open wire to terminal X2. Connect

the good wire, of equal gauge and length in the same cable, to terminal X1. Join these two wires at the distant end of the cable. Join the mates of these wires at both ends. All wires must be free from grounds and crosses. Connect one side of an a-c source (such as a tone or buzzer) to terminal BA— and the other side to the near end of the joined mates in the cable. Set the MULTIPLY BY dial at M1000, M100 or M10. Place one knife switch in the M position and the other in the MV position. Adjust the four rheostat dials for a bridge balance. Note the readings of these dials and of the MULTIPLY BY dial and use in formula below.

$$da = \frac{2LA}{A + R} \quad \text{where}$$

da = distance from instrument to open, in feet

L = length of cable, in feet

A = setting of MULTIPLY BY dial

R = sum of setting of four rheostat dials

b. OPEN LOCATION—PAIRS

The connections for this type measurement are shown in figure 4-9.

Remove screw 1, figure 4-1, to disconnect the galvanometer. Turn the BA switch to the OUT position. Connect a telephone receiver between terminals GA+ and GA—. Connect the open wire to terminal X1 and its distant end to a good ground. Connect the near end of its mate to a good ground and leave its distant end open. Connect one side of a 1 or 2 mf capacitor to terminal X2 and the other side to a good ground. Connect one side of an a-c source (such as a tone or buzzer) to terminal BA— and the other side to a good ground. Adjust the four rheostat dials for a bridge balance and note the sum of the settings of these dials. Use this value for R1 in the formula below. Then disconnect the near end of the faulty wire from terminal X1 and ground it. Disconnect the near end of the good wire from ground and connect it to terminal X1. Adjust the four rheostat dials for a bridge balance and note the sum of the settings of these rheostats. Use this value for R2 in the formula below.

$$da = \frac{R1L}{R2} \quad \text{where}$$

da = distance from instrument to open, in feet

R1 = first reading of rheostat dials, from above

R2 = second reading of rheostat dials, from above

L = length of cable, in feet

6. TO USE INSTRUMENT RHEOSTAT AS RESISTANCE BOX.

The four sections of the rheostat (operated by dials 1, 10, 100 and 1000) can be used as a four dial resistance box. The safe rating when used in this manner is .5 watt per coil.

To use the rheostat as a resistance box, remove screw 1, figure 4-1; place the one knife switch in the VR position; make connections to the rheostat at terminals X2 and GA—. Then depress (close) key G and make measurement with rheostat (resistance box).

SECTION 5

OPERATOR'S MAINTENANCE

1. BATTERY.

If the sensitivity of the instrument decreases to the extent that poor readings are obtained (that is, a small deflection of the galvanometer for a relatively large change in the bridge circuit), the dry cells should be replaced by fresh ones or in the case of a storage battery, it should be recharged.

To replace the dry cells in the instrument case, remove the two screws 1, figure 3-1, and the plate held by these screws. Remove the old dry cells from the compartment back of this plate. Then insert the new dry cells in series in the compartment (bottom end first) so that the center terminal on the last cell will make contact with the cover plate when it is replaced. Then replace the cover plate and the two screws for this plate.

2. GALVANOMETER.

If the galvanometer becomes damaged, remove screws 1 and 4, figure 4-1, and lift the complete galvanometer from the case. Then insert the new galvanometer in place and replace and tighten screws 1 and 4.

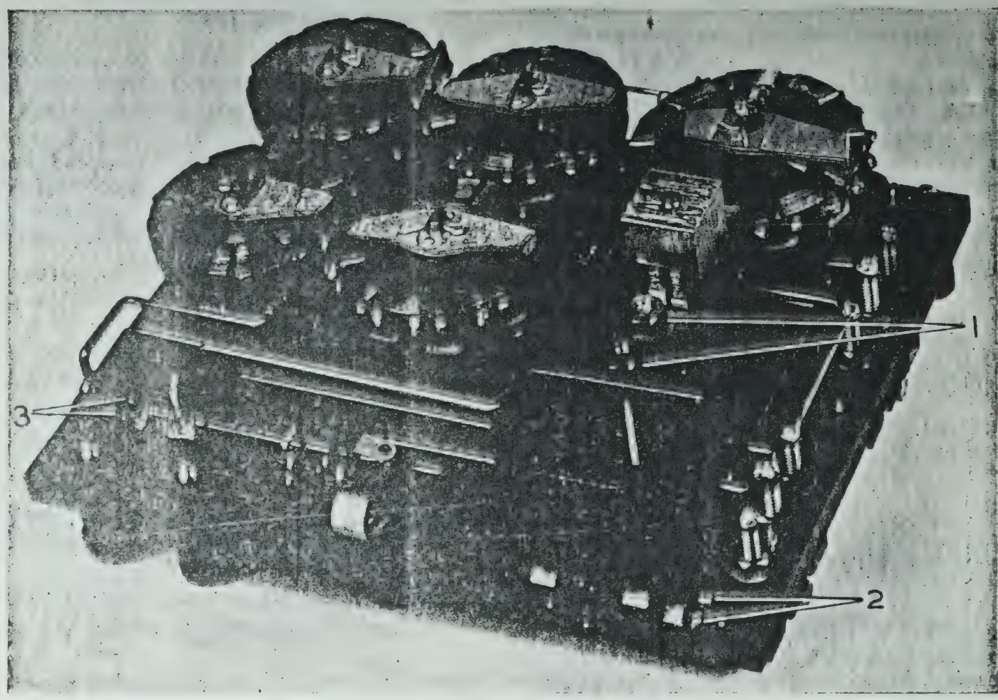

Figure 6-1. Resistance Bridge ZM-4/U, Under Side of Operating Panel from Rear Edge

SECTION 6

PREVENTIVE MAINTENANCE

1. GENERAL.

The instrument should be inspected at regular intervals to check or prevent any condition that might impair or totally disrupt its operation. To insure trouble free operation of the instrument, there are several practices which must be observed at all times. These are outlined below.

a. The galvanometer in this instrument is a sensitive and delicate piece of equipment but will withstand a reasonable amount of shock. The locking clamp 2, figure 4-1, locks the moving element when the instrument is not in use. Slide the CLAMP button in the direction of the arrow as far as it will go in order to lock the moving element before moving the instrument.

b. When using the four rheostat dials as a separate resistance box, the limiting current is determined by the highest dial in use. These current values are as follows:

1 ohm dial,	0.5 ampere
10 ohm dial,	0.16 ampere
100 ohm dial,	0.05 ampere
1000 ohm dial,	0.016 ampere

c. Keep the instrument in a dry place. Dampness will cause troublesome key and dial manipulation, and incorrect readings due to current leakage in the instrument. The wooden case, carrying strap and hardware will also be affected.

d. Inspect the dry cells in the instrument compartment at least twice weekly when the instrument is used in humid places. When the instrument is used only occasionally, remove the dry cells from the compartment after completing the tests. Never store the instrument with the dry cells in the instrument compartment. When installing the dry cells in the instrument compartment, be sure that the bottom (negative) terminal is inserted first so that the center (positive) terminal will be against the cover plate on the compartment when the plate is in position on the case.

e. When using an external d-c supply for the instrument, make sure that the correct polarity is observed when connecting this source to terminals BA+ and BA—. Do not use a voltage higher than 200 volts d-c. Furthermore, for any voltage in excess of 45 volts, use an exernal resistance in series with this voltage. This resistance should have a volume of 40 ohms for each volt over 45 volts.

f. The screws on the top plate, which includes the screws in the five dials and the galvanometer, should be kept tight. The four screws, which hold the plate in place, are shown at 5, figure 4-1, while those for the galvanometer are shown at 1 and 4, figure 4-1. The screws in the five dials are self-evident in figure 4-1. Furthermore, the nuts on the hinged section of the two knife switches should also be kept tight. In addition, the four screws 5, figure 4-1, should be removed and the top plate lifted from the instrument case in order to see that nuts 1, figure 6-1, and screws 2 and 3, figure 6-1, are tight and to inspect all soldered joints to see that they are also tight.

g. Rub a small amount of wax or clean heavy oil into the wooden case to prevent cracking. Be careful that none enters the lock or hinges. Work a few drops of Neatsfoot oil or equivalent into the leather strap after washing it with a mild soap. The frequency of application will depend upon the conditions under which the instrument is used.

h. The instrument is shipped from the manufacturer with a very thin film of Vaseline on the contacts of the MULTIPLY BY dial and the four rheostat dials. These dial contacts (see figure 6-1) should be inspected every six months to see if they are dry or dirty. When necessary, wipe the contacts with a soft, clean cloth to remove any old Vaseline and dirt. Then apply a very thin film of clean Vaseline. In order to obtain this very thin film of Vaseline on the contacts, it is suggested that a soft clean cloth be rubbed lightly over the contacts, after the Vaseline has been applied.

SECTION 7
CORRECTIVE MAINTENANCE

1. THEORY OF LOCALIZATION.

If the sensitivity (amount of deflection of the galvanometer for a given change in the four rheostat dials 1, 10, 100 and 1000) decreases to an unsatisfactory point, this may be due to weak dry cells in the instrument (or low voltage of the external source when used) or to dirty contacts of the MULTIPLY BY dial. Neither of these items affect the accuracy of the instrument.

If the galvanometer does not move, when it is known that the voltage support is satisfactory and the bridge circuit is closed, the galvanometer coil or suspensions may be damaged or the galvanometer CLAMP button may be in the clamp position or it may be jammed.

The instrument may be checked for accuracy by connecting a known value of resistance (a standard resistor or a resistance box), which is within the range of the instrument, to the X terminals and measuring this resistance.

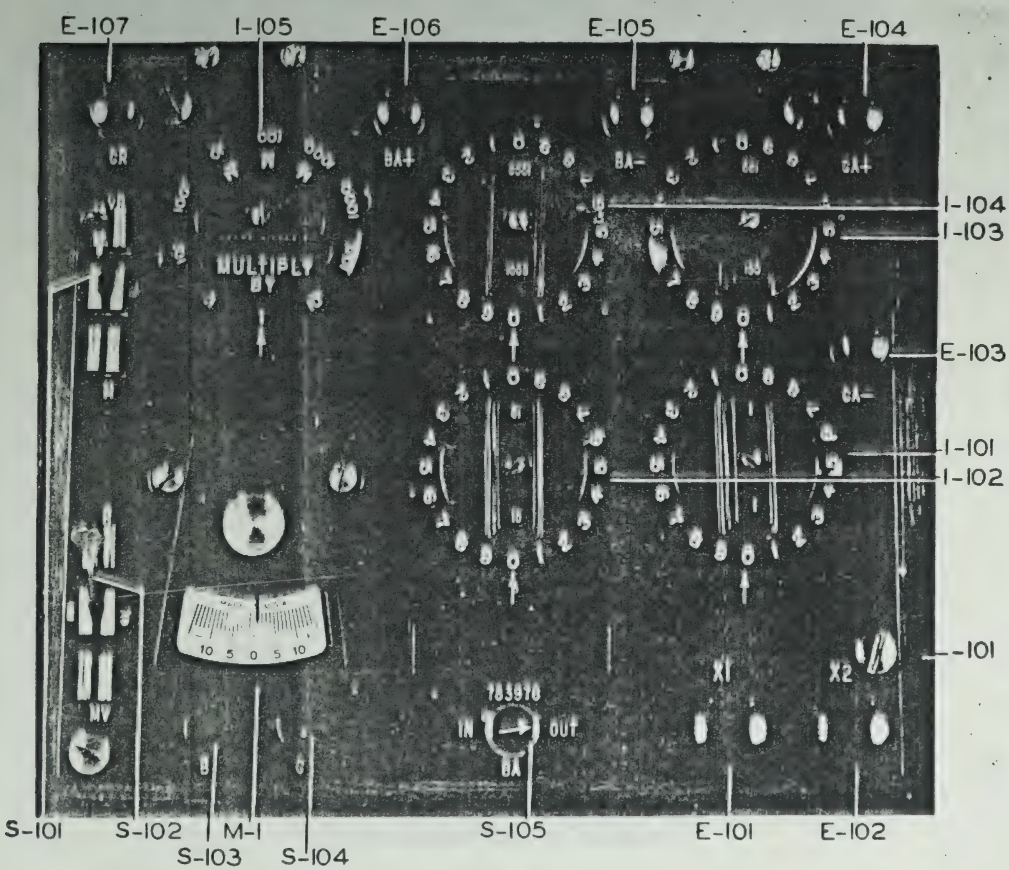

Figure 7-1. Resistance Bridge ZM/4U, Operating Panel

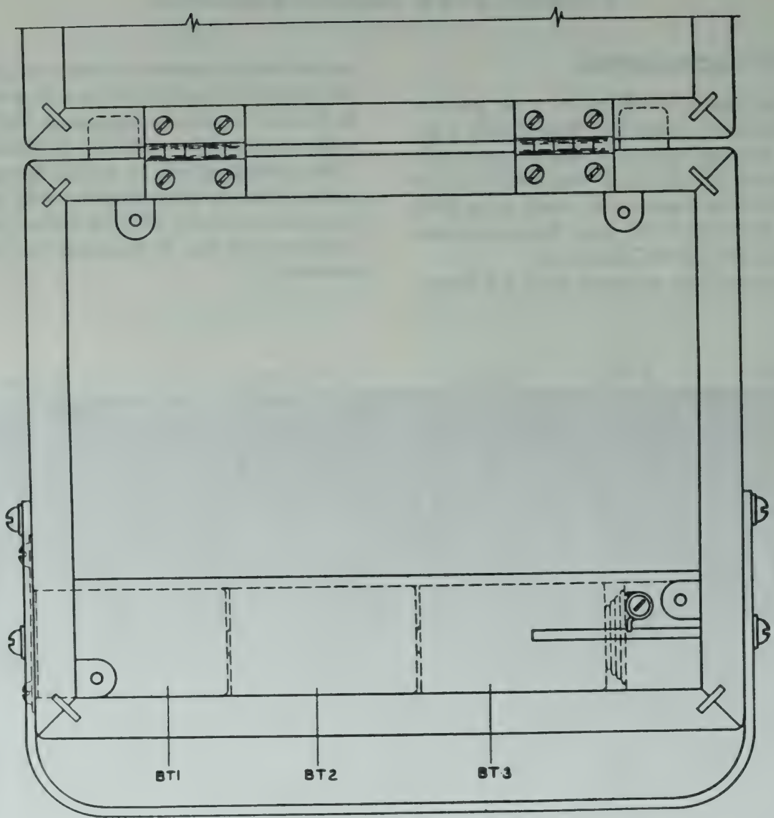

Figure 7-2. Resistance Bridge ZM-4/U Showing Dry Cell Compartment

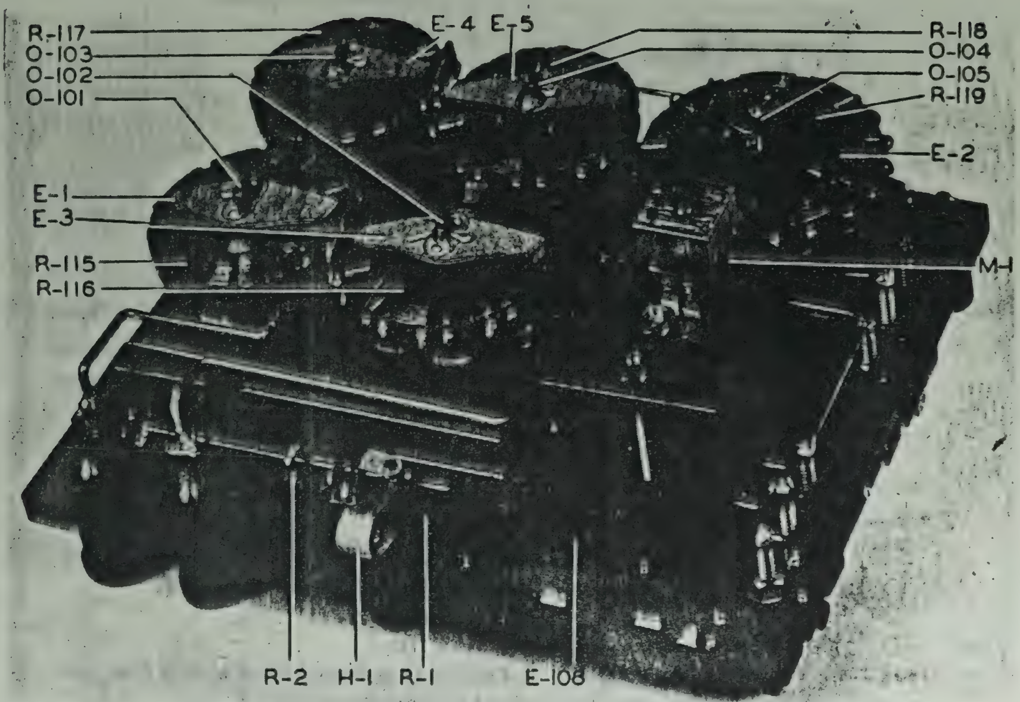

Figure 7-3. Resistance Bridge ZM-4/U, Under Side of Operating Panel from Front Edge

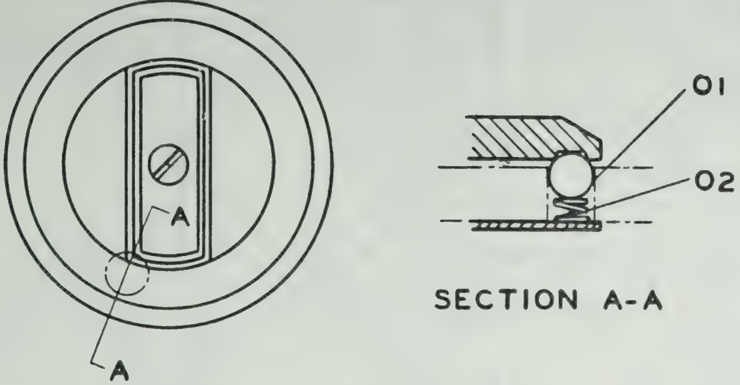

Figure 7-4. Resistance Bridge ZM-4/U, Detail of Click Ball and Spring

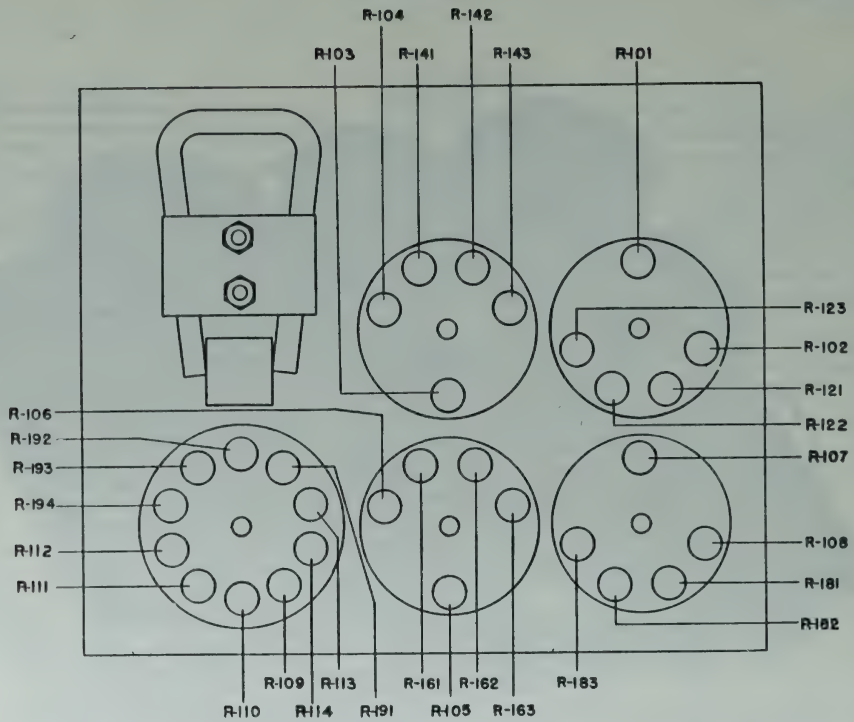

Figure 7-5. Resistance Bridge ZM-4/U, Under Side of Operating Panel from Rear Edge

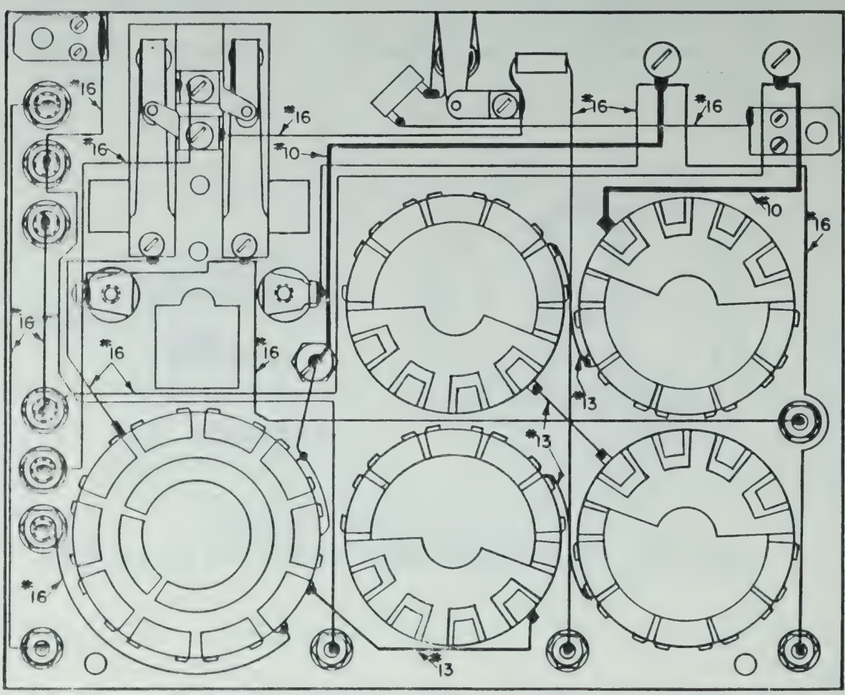

Figure 7-6. Resistance Bridge ZM-4/U, Actual Wiring and Wire Sizes

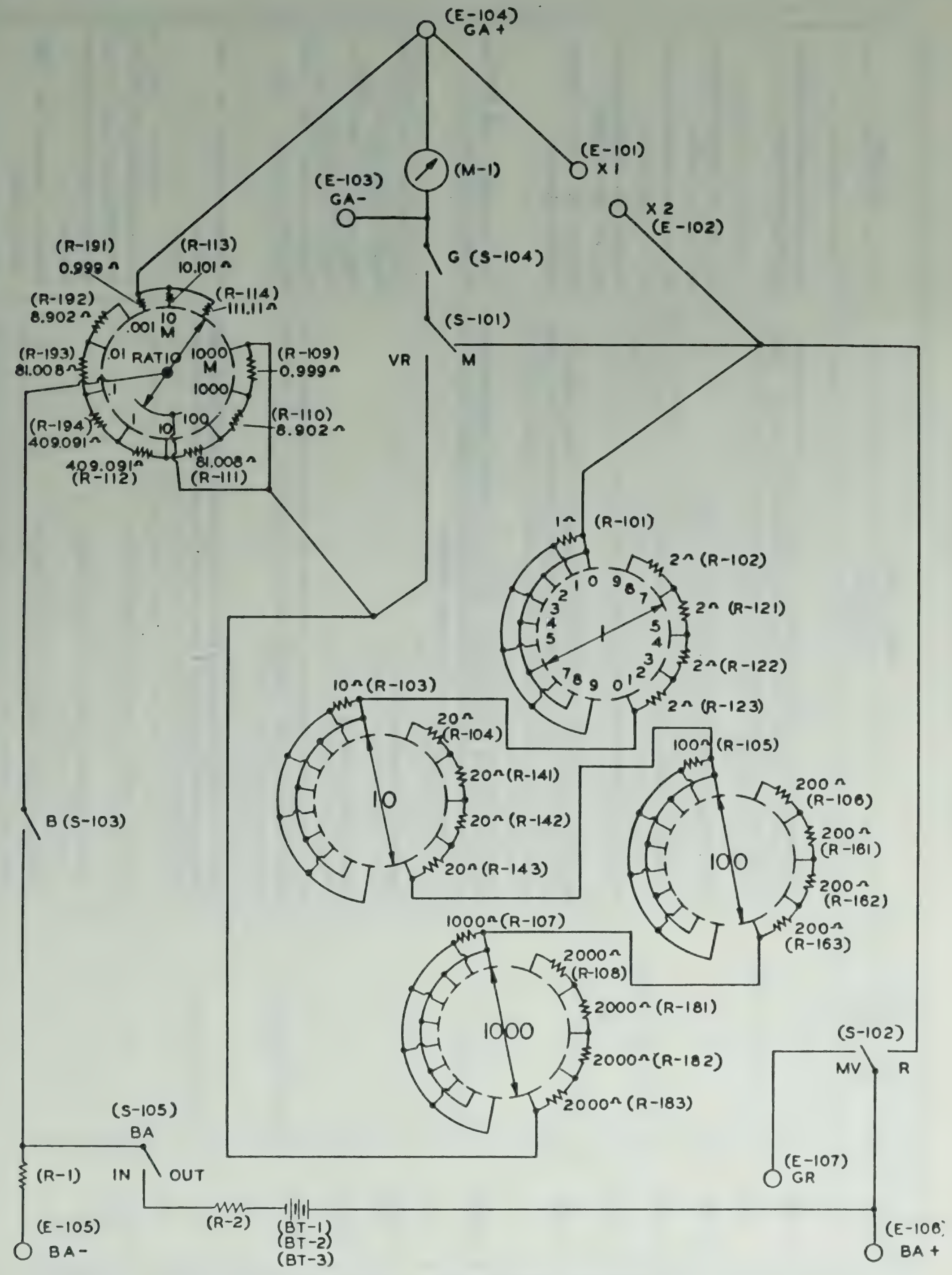

Figure 7-7. Resistance Bridge ZM-4/U
Elementary Wiring

TABLE 8-1. TABLE OF REPLACEABLE PARTS

REF. DESIG.	STOCK NUMBERS— SIGNAL CORPS, STD. NAVY, AIR FORCE	NAME OF PART AND DESCRIPTION	FUNCTION
A-101	*	Mounting resistor: bakelite molding including fixed contact assembly; 2 1/4" diam x 1 1/2" h; two tapped mtg holes #8-32 on 5/8" radius spaced 180 deg apart; Leeds & North part/dwg S-15-A; p/o R-115	Supports five resistors comprising 1 ohm rheostat
A-102	*	Mounting, resistor: same as A-101, p/o R-116	Supports five resistors comprising 10 ohm rheostat
A-103	*	Mounting, resistor: same as A-101, p/o R-117	Supports five resistors comprising 100 ohm rheostat
A-104	*	Mounting, resistor: same as A-101, p/o R-118	Supports five resistors comprising 1000 ohm rheostat
A-105	*	Mounting, resistor: bakelite molding including fixed contact assembly; 2 1/2" diam x 3" h; two tapped mtg holes #8-32 on 15/16" radius spaced 180 deg apart; Leeds & North part/dwg S-2-A; p/o R-119	Supports ten resistors comprising ratio rheostat
BT-1	— N17-B-7210	Battery, dry: 1 1/2 V cylindrical; 2 3/8" lg x 1-5/16" diam; metallic case; post for one terminal, bottom of case other terminal; Ray-O-Vac No. 2LP size D; Leeds & North part Std. 986	Used with BT-2 and BT-3 to supply bridge circuit
BT-2		Battery, dry: same as BT-1	Used with BT-1 and BT-3 to supply bridge circuit
BT-3		Battery, dry: same as BT-1	Used with BT-1 and BT-2 to supply bridge circuit
E-1	— N17-C-81992-7426 *	Contact assembly: consists of one pile up type contact assembly of three leaves; 1-21/32" lg x 5/8" wd x 3/8" h overall; Leeds & North part/dwg S-15-D; p/o R-115	Movable contacts for 1 ohm rheostat
E-2	— N17-C-81993-2876 *	Contact assembly: consists of one pile up contact assembly of three leaves; 1-11/16" lg x 19/32" wd x 5/16" h overall; Leeds & North part/dwg S-2-D; p/o R-119	Movable contacts for ratio rheostat
E-3	*	Contact assembly: same as E-1, p/o R-116	Movable contacts for 10 ohm rheostat
E-4	*	Contact assembly: same as E-1, p/o R-117	Movable contacts for 100 ohm rheostat
E-5	*	Contact assembly: same as E-1, p/o R-118	Movable contacts for 1000 ohm rheostat

* Not furnished as a maintenance part. If failure occurs, do not request replacement unless the part cannot be repaired or fabricated.

E-101		Post, binding: screw type; 11/16" diam overall x 1-3/16" lg extended above mtg surface, tapped for #10-32 mtg stud 1" lg; bakelite cap and base; $1\frac{3}{8}$" lg x 1/16" thk x $\frac{1}{8}$" wd brass locating and connection pin; knurled removable cap; Leeds & North part Std. 19; Leeds & North dwg SD-9 Sk 1	X-1 connection post on panel
E-102		Post, binding: same as E-101	X-2 connection post on panel
E-103		Post, binding: screw type; $\frac{5}{8}$" diam overall x $\frac{7}{8}$" lg extended above mtg surface, #8-32 x $\frac{5}{8}$" lg mtg stem; bakelite cap and base; 0.0935" diam wire hole in stem; #42 pin x 1/16" lg to locate base; non-removable knurled cap; Eby Ensign B bakelite binding post; Leeds & North part/dwg Std. 2393	GA— connection post on panel
E-104		Post, binding: same as E-103	GA+ connection post on panel
E-105		Post, binding: same as E-103	BA— connection post on panel
E-106		Post, binding: same as E-103	BA+ connection post on panel
E-107		Post, binding: same as E-103	GR connection post on panel
E-108	*	Magnet: high grade magnet steel, black lacquer finish; 11000 lines minimum flux; horseshoe shape 2" wd x $1\frac{1}{4}$" h x 3" lg overall; N on north pole; Leeds & North part/dwg PI-18	Used with galvanometer
H-1	— N43-N-4878-6155 #	Nut, hexagon: brass, nickel plate; 5/16"-26 thread; $\frac{1}{8}$" thk x $\frac{3}{8}$" across flats; Leeds & North part/dwg Std. 416; p/o S-105	Nut for BA key
I-101	— N16-D-46553-1166	Dial: u/w Leeds & North S-15 resistor unit; black bakelite, polished; circular dial with integral rectangular knob; $1\frac{7}{8}$" diam x 1" h overall; single axial #27 mtg hole; engraved O, 1 to 9 twice around bevelled edge with 1 engraved at top of knob; base indented for positioning device; Leeds & North part/dwg S-15-E-1	Positions 1 ohm rheostat
I-102	— N16-D-46553-1169	Dial: same as I-101 except has numeral 10 at top of knob	Positions 10 ohm rheostat
I-103	— N16-D-46553-1172	Dial: same as I-101 except has numeral 100 at top of knob	Positions 100 ohm rheostat

* Not furnished as a maintenance part. If failure occurs, do not request replacement unless the part cannot be repaired or fabricated.

\# Not furnished as a maintenance part for Bureau of Ships activities. If failure occurs, do not request replacement unless the part cannot be repaired or fabricated.

TABLE 8-1. TABLE OF REPLACEABLE PARTS

REF. DESIG.	STOCK NUMBERS— SIGNAL CORPS, STD. NAVY, AIR FORCE	NAME OF PART AND DESCRIPTION	FUNCTION
I-104	— N16-D-46553-1175	Dial: same as I-101 except has numeral 1000 at top of knob	Positions 1000 ohm rheostat
I-105	— N16-D-46553-1178	Dial: u/w Leeds & North S-2-S ratio resistor unit; black bakelite, polished; circular dial with integral rectangular knob; 1⅞″ diam x 1″ h overall; single axial #27 mtg hole; engraved .001, .01, .1, 1, 10, 100, 1000, 100, 10; base indented for positioning device; Leeds & North part/dwg S-2-M	Positions ratio rheostat
M-1	— N17-M-25764-8001	Meter, Galvanometer: DC moving coil type; range —15 to 0 to +15 μA; L-shaped, metal and plastic; 23/32″ barrel, 2-21/32″ deep behind flange, 2-15/16″ lg x 2-1/16″ wd flange; 250 ohms resistance; 30 scale divisions, black numerals on white background; two 11/16″ diam mtg holes spaced 1⅝″ apart; Leeds & North part/dwg PI-24-C	Indicate balance of bridge circuit
O-1	— G77-B-999-56018-0200	Ball, positioning: high carbon chrome alloy steel, standard finish; 9/32″ diam sphere; Leeds & North part S-15-K	Ball for click positioning of 1 ohm dial
O-2	— N17-S-46657-8091	Spring: helical compression type; 0.023″ diam steel music wire; 5/16″ lg x 7/32″ diam overall; 5 turns; Leeds & North part/dwg S-1-I	Spring for click ball under 1 ohm dial
O-3		Ball, positioning: same as O-1	Ball for click positioning of 10 ohm dial
O-4		Ball, positioning: same as O-1	Ball for click positioning of 100 ohm dial
O-5		Ball, positioning: same as O-1	Ball for click positioning of 1000 ohm dial
O-6		Ball, positioning: same as O-1	Ball for click positioning of ratio dial
O-7		Spring: same as O-2	Spring for click ball under 10 ohm dial
O-8		Spring: same as O-2	Spring for click ball under 100 ohm dial
O-9		Spring: same as O-2	Spring for click ball under 1000 ohm dial
O-10		Spring: same as O-2	Spring for click ball under ratio dial

O-101	*	Shaft: part of Leeds & North ratio unit S-2; brass; 1/4" diam x 2 3/4" overall; 6-32 tapped hole in one end to mount dial, other end tapered with #51 hole through shaft to secure contact assembly; Leeds & North part/dwg S-15-B; p/o R-115	Rotates contacts on 1 ohm rheostat
O-102	*	Shaft: same as O-101, p/o R-116	Rotates contacts on 10 ohm rheostat
O-103	*	Shaft: same as O-101, p/o R-117	Rotates contacts on 100 ohm rheostat
O-104	*	Shaft: same as O-101, p/o R-118	Rotates contacts on 1000 ohm rheostat
O-105	*	Shaft: part of Leeds & North ratio unit S-2 brass; 1/4" diam x 2 3/4" lg with 3/4" diam shoulder at one end; 6-32 tapped hole and two 1/16" diam pins to mount dial, other end tapered with 1/16" hole through shaft to secure contact assembly; Leeds & North part/dwg S-2-BD; p/o R-119	Rotates contacts on ratio unit
O-201	*	Shaft: operates switch contacts; u/w Leeds & North part Std. 131 switch button; brass; 0.1873 rod x 1 1/8" lg; 8-32 thread 1/8" long at one end, 1/32" long radial pin 1/8" from opposite end; Leeds & North part Std. 417; p/o S-105	Plunger for BA key
R-1	— N16-R-65327-1025	Resistor, fixed: coil type; #32 E manganin wire; 10 ohms ±5%; 1" lg x 3/4" wd overall; two solder lug terminals; Leeds & North part/dwg Std. 1291-10	In series with internal battery
R-2	— N-16R-49922-811	Resistor, fixed: radio type; metallized insulated composition; JAN type RC20BF102K; 1000 ohms ±10%; 1/2" w; 13/32" lg x 1/8" diam; salt water immersion resistant; two axial wire leads; Spec JAN-R-11	In series with external battery
R-101		Resistor, fixed: coil type; 1 ohm ±0.05%; 0.6 watt; 1 1/8" lg x 9/16" diam; two wire leads; mounts on 3/8" diam stud; Leeds & North part 10-5-13-3; p/o R-115	Unit of 1 ohm rheostat
R-102	— N16-R-79855-5505	Resistor, fixed: coil type; 2 ohms ±0.05%; 0.6 watt; 1 1/8" lg x 9/16" diam; two wire leads; mounts on 3/8" diam stud; Leeds & North part 10-5-13-4; p/o R-115	Unit of 1 ohm rheostat
R-103	— N16-R-79934-4501	Resistor, fixed: coil type; 10 ohms ±0.05%; 0.6 watt; 1 1/8" lg x 9/16" diam; two wire leads; mounts on 3/8" diam stud; Leeds & North part 10-5-13-5; p/o R-116	Unit of 10 ohm rheostat
R-104	— N16-R-79992-1005	Resistor, fixed: coil type; 20 ohms ±0.05%; 0.6 watt; 1 1/8" lg x 9/16" diam; two wire leads; mounts on 3/8" diam stud; Leeds & North part 10-5-13-5; p/o R-116	Unit of 10 ohm rheostat

* Not furnished as a maintenance part. If failure occurs, do not request replacement unless the part cannot be repaired or fabricated.

TABLE 8-1. TABLE OF REPLACEABLE PARTS

REF. DESIG.	STOCK NUMBERS— SIGNAL CORPS, STD. NAVY, AIR FORCE	NAME OF PART AND DESCRIPTION	FUNCTION
R-105	— N16-R-80096-1005	Resistor, fixed: coil type; 100 ohms ±0.05%; 0.6 watt; 1⅛" lg x 9/16" diam; two wire leads; mounts on ⅜" diam stud; Leeds & North part 10-5-13-7; p/o R-117	Unit of 100 ohm rheostat
R-106	— N16-R-80135-1005	Resistor, fixed: coil type; 200 ohms ±0.05%; 0.6 watt; 1⅛" lg x 9/16" diam; two wire leads; mounts on ⅜" diam stud; Leeds & North part 10-5-13-8; p/o R-117	Unit of 100 ohm rheostat
R-107	— N16-R-80232-5505	Resistor, fixed; coil type; 1000 ohms ±0.05%; 0.6 watt; 1⅛" lg x 9/16" diam; two wire leads; mounts on ⅜" diam stud; Leeds & North part 10-5-13-9; p/o R-118	Unit of 1000 ohm rheostat
R-108	— N16-R-80260-7005	Resistor, fixed: coil type; 2000 ohms ±0.05%; 0.6 watt; 1⅛" lg x 9/16" diam; two wire leads; mounts on ⅜" diam stud; Leeds & North part 10-5-13-10; p/o R-118	Unit of 1000 ohm rheostat
R-109	— N16-R-79827-3819	Resistor, fixed: coil type; 0.999 ohms ±0.03%; 0.4 watt; 1⅛" lg x 9/16" diam; two wire leads; mounts on ⅜" diam stud; Leeds & North part 10-21-13-2, 0.999 ohms; p/o R-119. Listed for reference only	Unit of ratio rheostat
R-110	— N16-R-79924-7722	Resistor, fixed: coil type; 8.902 ohms ±0.03%; 0.4 watt; 1⅛" lg x 9/16" diam; two wire leads; mounts on ⅜" diam stud; Leeds & North part 10-21-13-2; 8.902 ohms; p/o R-119. Listed for reference only	Unit of ratio rheostat
R-111	— N16-R-80084-2544	Resistor, fixed: coil type; 81.008 ohms ±0.03%; 0.4 watt; 1⅛" lg x 9/16" diam; two wire leads; mounts on ⅜" diam stud; Leeds & North part 10-21-13-2, 81.008 ohms; p/o R-119. Listed for reference only	Unit of ratio rheostat
R-112	— N16-R-80171-5346	Resistor, fixed: coil type; 409.091 ohms ±0.03%; 0.4 watt; 1⅛" lg x 9/16" diam; two wire leads; mounts on ⅜" diam stud; Leeds & North part 10-21-13-2, 409.091 ohms; p/o R-119. Listed for reference only	Unit of ratio rheostat
R-113	— N16-R-79937-1393	Resistor, fixed: coil type; 10.101 ohms ±0.03%; 0.4 watt; 1⅛" lg x 9/16" diam; two wire leads; mounts on ⅜" diam stud; Leeds & North part 10-21-13-3, 10.101 ohms; p/o R-119. Listed for reference only	Unit of ratio rheostat

* Not furnished as a maintenance part. If failure occurs, do not request replacement unless the part cannot be repaired or fabricated.

R-114	— N16-R-80103-7002	Resistor, fixed: coil type; 111.111 ohms ±0.03%; 0.4 watt; 1⅛″ lg x 9/16″ diam; two wire leads; mounts on ⅜″ diam stud; Leeds & North part 10-21-13-3, 111.111 ohms; p/o R-119. Listed for reference only	Unit of ratio rheostat
R-115	*	Resistor Assembly, variable: consists of 5 resistors on bakelite mtg complete with movable and fixed contacts; provides 9 ohms resistance in 1 ohm steps; 2¼″ diam x approx 3″ h overall; two tapped 8-32 mtg holes on ⅝″ radius spaced 180 deg apart; consists of A-101, E-1, O-101, R-101, R-102, R-121, R-122 and R-123; Leeds & North part/dwg S-15-1	1 ohm rheostat
R-116	*	Resistor Assembly, variable: consists of 5 resistors on bakelite mtg complete with movable and fixed contacts; provides 90 ohms resistance in 10 ohm steps: 2¼″ diam x approx 3″ h overall; two tapped 8-32 mtg holes on ⅝″ radius spaced 180 deg apart; consists of A-102, E-3, O-102, R-103, R-104, R-141, R-142 and R-143; Leeds & North part/dwg S-15-10	10 ohm rheostat
R-117	*	Resistor Assembly, variable: consists of 5 resistors on bakelite mtg complete with movable and fixed contacts; provides 900 ohms in 100 ohm steps; 2¼″ diam x approx 3″ h overall; two tapped holes on ⅝″ radius spaced 180 deg apart; consists of A-103, E-4, O-103, R-105, R-106, R-161, R-162 and R-163; Leeds & North part/dwg S-15-100	100 ohm rheostat
R-118	*	Resistor Assembly, variable: consists of 5 resistors on bakelite mtg complete with movable and fixed contacts; provides 9000 ohms in 1000 ohm steps; 2¼″ diam x approx 3″ h overall; two tapped holes on ⅝″ radius spaced 180 deg apart; consists of A-104, E-5, O-104, R-107, R-108, R-181, R-182 and R-183; Leeds & North part/dwg S-15-1000	1000 ohm rheostat
R-119	— N16-R-93288-2716	Resistor Assembly, variable: consists of 10 resistors on bakelite mtg complete with movable and fixed contacts; provides ratios of .001 to 1000 in multiples of 10; 2½″ diam x approx 3″ h overall; two tapped 8-32 mtg holes on 15/16″ radius spaced 180 deg apart; consists of A-105, E-2, O-105, R-109 to R-114 incl, and R-191 to R-194 incl; Leeds & North part/dwg S-2-S	Ratio rheostat
R-121		Resistor, fixed: same as R-102, p/o R-115	Unit of 1 ohm rheostat
R-122		Resistor, fixed: same as R-102, p/o R-115	Unit of 1 ohm rheostat

* Not furnished as a maintenance part. If failure occurs, do not request replacement unless the part cannot be repaired or fabricated.

TABLE 8-1. TABLE OF REPLACEABLE PARTS

REF. DESIG.	STOCK NUMBERS— SIGNAL CORPS, STD. NAVY, AIR FORCE	NAME OF PART AND DESCRIPTION	FUNCTION
R-123		Resistor, fixed: same as R-102, p/o R-115	Unit of 1 ohm rheostat
R-141		Resistor, fixed: same as R-104, p/o R-116	Unit of 10 ohm rheostat
R-142		Resistor, fixed: same as R-104, p/o R-116	Unit of 10 ohm rheostat
R-143		Resistor, fixed: same as R-104, p/o R-116	Unit of 10 ohm rheostat
R-161		Resistor, fixed: same as R-106, p/o R-117	Unit of 100 ohm rheostat
R-162		Resistor, fixed: same as R-106, p/o R-117	Unit of 100 ohm rheostat
R-163		Resistor, fixed: same as R-106, p/o R-117	Unit of 100 ohm rheostat
R-181		Resistor, fixed: same as R-108, p/o R-118	Unit of 1000 ohm rheostat
R-182		Resistor, fixed: same as R-108, p/o R-118	Unit of 1000 ohm rheostat
R-183		Resistor, fixed: same as R-108, p/o R-118	Unit of 1000 ohm rheostat
R-191		Resistor, fixed: same as R-109, p/o R-119	Unit of ratio rheostat
R-192		Resistor, fixed: same as R-110, p/o R-119	Unit of ratio rheostat
R-193		Resistor, fixed: same as R-111, p/o R-119	Unit of ratio rheostat
R-194		Resistor, fixed: same as R-112, p/o R-119	Unit of ratio rheostat
S-101	*	Switch, knife: SPDT; brass, nickel-plated knife and contacts; non-fusable; 2⅛″ lg x ⅜″ wd x 1¾″ h overall; p/o 2M-4/U resistance bridge; mounted on bakelite top plate; connections soldered to mtg lugs; three ¼″ mtg holes 9/16″ apart on mtg ctr line; Leeds & North details 5, 6, 7 and 8 of dwg 845	VR-M switch on top plate
S-102	*	Switch, knife: same as S-101	MV-R switch on top plate

* Not furnished as a maintenance part. If failure occurs, do not request replacement unless the part cannot be repaired or fabricated.

S-103	*	Switch, push: SPST, 3/4″ high x 3/8″ wd x 2 1/8″ lg overall; momentary action, normally open; solder lug terminals; mounted to panel with two 1/8″ 6-32 RHB screws; Leeds & North part assembly S3A, S3C, S3G and S1003E	B switch on panel
S-104	*	Switch, push: same as S-103	G switch on panel
S-105	#	Switch assembly: p/o 2M-4/U resistance bridge; Leeds & North BA key for Cat 5300 test set; approx 1 1/2″ h x 1″ wd x 1″ thk overall; mounts through 5/16″ hole in top plate; arrow engraved on bakelite head; push to make contact and rotate 180 deg to lock in make position; Leeds & North details 1, 2, 4, 15, 17, 20 and 23 of dwg 845	Battery switch on panel
-101		Cabinet: oak, natural finish; 8 1/8″ wd x 5 5/8″ h x 9 1/2″ lg overall; 8 rubber bumpers four on bottom and four on back; leather hand carrying strap; hinged lid 1 5/8″ deep; clasp fastener; Leeds & North dwg 846-3	Housing for instrument

* Not furnished as a maintenance part. If failure occurs, do not request replacement unless the part cannot be repaired or fabricated.

Not furnished as a maintenance part for Bureau of Ships activities. If failure occurs, do not request replacement unless the part cannot be repaired or fabricated.

TABLE 8-2. CROSS REFERENCE PARTS LIST

STD. NAVY STOCK NO.	KEY SYMBOL
G77-B-999-56018-0200	O-1
N16-D-46553-1166	1-101
N16-D-46553-1169	1-102
N16-D-46553-1172	1-103
N16-D-46553-1175	1-104
N16D-46553-1178	1-105
N16-R-49922-811	R-2
N16-R-65325-1025	R-1
N16-R-79827-3819	R-109
N16-R-79855-5505	R-102
N16-R-79924-7722	R-110
N16-R-79934-4501	R-103
N16-R-79937-1393	R-113
N16-R-79992-1005	R-104
N16-R-80084-2544	R-111
N16-R-80096-1005	R-105
N16-R-80103-7002	R-114
N16-R-80135-1005	R-106
N16-R-80171-5346	R-112
N16-R-80232-5505	R-107
N16-R-80260-7005	R-108
N16-R-93288-2716	R-119
N17-B-7210	BT-1
N17-C-81992-7426	E-1
N17-C-81993-2876	E-2
N17-M-25764-8001	M-1
N17-S-46657-8091	O-2
N43-N-4878-6155	H-1